# MANGANESE
IN THE
# FOUNDRY

Published by
KENDALL & FLICK
Washington, D. C.

PRINTED BY
BYRON S. ADAMS
WASHINGTON, D. C.

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A DESCRIPTION OF ITS METALLURGICAL CHARACTER, INFLUENCES AND VALUE IN CAST-IRON, WITH DIRECTIONS FOR USE.

By J. E. CARTWRIGHT

1903

KENDALL & FLICK

WASHINGTON, D. C.

Revised Edition

# PART I.

The increasing use of manganese in foundry practice and the frequent discussions in foundry associations have given the impression that a monograph on the subject, relating briefly a history of the metal manganese, its progress in industrial uses, metallurgical characteristics, and methods of using it for different classes of foundry work, might prove of some value to those engaged in operating iron foundries. The following pages are largely a compilation of statements from the works of leading writers on metallurgy, Howe, Roberts-Austin, Turner, Hiorns and others.

Probably no better introduction to the subject can be found than the words of Deshayes in his paper on the

## Position of Manganese in Modern Industry.

"No body among the metals and the metalloids (titanium, tungsten, chromium, phosphorus, etc.,) has occupied a more prominent position in modern metallurgy than manganese, and it is chiefly due to its great affinity for oxygen. When this substance was discovered in 1774 by Gahn, no one would have thought that the new element, so delicate by itself, without any direct industrial use, would become, in the middle of the Nineteenth Century, one of the most powerful and necessary instruments for the success of the Bessemer process,

as well for its deoxidizing properties as for the qualities which it imparts to steel, increasing its resistance, its durability and its elasticity. * * * Without entering into a complete history (which is beyond the task here assumed), it will not be without interest to recall how, when manganese was first obtained in a pure state, it was supposed that it would remain simply an object of curiosity in the laboratory; but when its presence was proved in Spiegeleisen and when it came to be considered an essential ingredient, in the best German and English works, for cutlery steel, then we find its qualities become better and better appreciated."—[M. V. Deshayes, Bull. Soc. Chim. Paris, XXXVI; page 184.]

## Manganese.

Symbol, Mn. Atomic Wt. 55. Specific Grav., 8. Manganese belongs to the iron group of metals. It is a grayish white metal, never occurring native. The pure metal is obtained by reduction of its oxide. It oxidizes rapidly in the air, and decomposes water slowly at the ordinary temperature. It alloys readily with iron, steel and copper, and its chief use is in the formation of such alloys. It alloys with iron in all ratios. It is not used in the unalloyed state. In one or the other of its various forms manganese is widely distributed in nature; one of the most common is pyrolusite (manganese dioxide or peroxide), $Mn\ O_2$., and this is the most valuable of its ores. Manganese forms two basic, two indifferent, and two acid oxides. The oxides of manganese and many of its salts find extended application in the arts.

**Ferro-Manganese.** "This may be considered a variety of pig iron in which the iron is replaced largely by manganese. It is produced by smelt-

ing in a blast furnace from ores rich in oxide of manganese. and it is possible to obtain a product having as much as 87% of manganese. When this metal contains about 20% manganese its fracture shows large crystalline cleavage, and is termed spiegeleisen. The variety known as ferro-manganese is a hard crystalline metal, but the fractured surface does not present the large cleavage planes characteristic of spiegel."—[Hiorns.]

The authorities are not agreed as to the line dividing spiegeleisen and ferro-manganese. Some class as spiegel all pig iron containing 5% to 20% manganese; and ferro-manganese all such metal containing a higher percentage of manganese than 20%. Others use 40% manganese as the dividing line, all below that percentage being spiegel, and all above it, ferro-manganese. The usual market grade of ferro-manganese now sold contains 80% manganese.

**Carbon and Manganese in Iron.** Any study of the action and influences of manganese in iron or steel must necessarily be made in connection with carbon, having in view the carbon contents and the influence of the manganese and carbon upon each other, and of both elements jointly and separately upon iron.

"It may be doubted whether the exact influence (on iron) exercised by varying proportions of carbon has been accurately determined. A distinguished authority (Mr. H. M. Howe) thinks that it is not yet known. He points out that he has plotted in a single curve the results of over 2,500 tests, and yet the conclusion he arrives at is that we are not at present able to quantitatively express the effect of carbon. The fact is that

metallurgists are only beginning to realize that the effect of elements in the presence of each other is very complicated, and that it is absolutely necessary to study the effect of any given element on an absolutely pure mass of the metal to be tested."—[Roberts-Austin.]

**Total Carbon, or Saturation Point for Carbon.** "The quantity of carbon with which molten iron can combine (=combined + graphitic carbon of the solidified iron) depends chiefly on the percentage of silicon, sulphur and manganese which it contains. The former two elements lower the saturation point for carbon, while manganese raises it. Chemically pure iron can apparently only combine with about 4.63% of carbon."—[Howe.]

It will be found, therefore, that irons high in manganese are also high in combined carbon, unless a high percentage of silicon is present at the same time, in which case the tendency of the manganese to raise the percentage of carbon may be counteracted by the influence of the silicon to lower it. Ferro-manganese often contains about 5.5% carbon and occasionally 7%. With increasing manganese the saturation point for carbon rises as follows:

| | | | | | |
|---|---|---|---|---|---|
| Manganese | 10 to 20.% | 35.% | 50.% | 65.% | 80.% |
| Corresponding Saturation points for carbon. | 5.% | 5.5% | 6.% | 6.5% | 7.% |

**Volatility of Manganese.** Manganese appears to volatilize with considerable rapidity at a white heat. Thus, Jordan states that at a French blast-furnace 10% of the manganese charged could not be accounted for by the contents of metal, slag and dust. Further, ferro-manganese of 84.9% manganese lost 4% of its manganese on being ex-

posed to the heat of a wind-furnace for 2½ hours in a brasqued crucible.

"If an iron containing manganese is remelted more or less of the maganese will escape by volatilization, and by oxidation with the other elements in the iron."—[Keep.]

**Fusibility.** The fusion point of manganese is 1,900° C.

**Desulphurization by Manganese.** "The desulphurizing effect of manganese is much more marked than that of silicon. With iron such as is used for the basic process the silicon is low (usually 1.% or less) and sulphur would therefore be present in relatively large quantities if manganese were not added to the charge in sufficient quantity to give some 1.5% of manganese in the metal.—[Turner.]

Turner also says: "Manganese leads to the much more perfect removal of sulphur, which is eliminated in the form of manganous sulphide (Mn S.); this floats to the surface of the molten iron and forms part of the slag which collects at the top of the metal. This fact, which has been long observed, forms the basis of the process of sulphur elimination recently patented by Massenez, in which manganese is added to molten iron rich in sulphur (as high as 2% or 3% sulphur), which is thus purified and rendered suitable for the use of steel makers."

(For description of Massenez process of desulphurization of pig iron, see Sci. Amer. Sup. No. 829.)

Walrand, after melting sulphurous cast-iron in one crucible and manganese under lime in another, poured the cast-iron into the manganese and stirred the mixture for a minute, when an insup-

portable odor of sulphurous acid arose from the supernatant slag; the sulphur in the cast-iron fell from 0.50 to 0.06%.

Sulphur and manganese probably combined, and rose to the surface, when, exposed to the air, the sulphur became rapidly oxidized.—[Howe.]

Akerman considers that manganese drags sulphur into the blast-furnace slag even more powerfully than calcium does.

In three sets of experiments (1) on phosphoric, (2) on sulphurous, (3) on siliceous cast-iron respectively, each melted, (A) alone, and (B) with metallic manganese, Caron found that the addition of manganese energetically expelled sulphur, increased the percentage of silicon (by reducing it from the walls of the cupola), but had little effect on phosphorous.

"If sulphur be present, some of the manganese will be likely to unite with it and escape, thus reducing the amount of both elements in the casting. Hence, in remelting irons, some of the sulphur which has entered from the fuel with which the iron is melted will very likely unite with some of the manganese in the irons which makes up the mixture and escape."—[Keep, Vol. 20, page 291, Trans. Amer, I. M. E.]

"Regarding sulphur; during my experiments whenever I have put ferro-manganese into the ladle from our cupola sulphur became apparent to the smell, which I presume indicates that the manganese eliminates the sulphur. It seems to me, moreover, that in Mr. Howe's work on steel this is so conclusively proved as to make further experiment unnecessary.—[Ibid, page 314.—Discussion.]

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**Order of Oxidation.** " Next to silicon, manganese is the most easily oxidizable element in pig-iron. Manganese, therefore, protects the iron from oxidation until it is itself completely oxidized."—[Wedding.]

**Occlusion of Gases.** "Metals when melted in contact with air or other gases, absorb them more or less, and retain a portion after solidification ; the portion thus retained is said to be occluded." —[Hiorns.]

" It is well know that at the conclusion of the Bessemer process oxygen from the air blown through the metal becomes intimately associated with the iron ; but the manner in which the oxygen is held, whether as oxide, or as dissolved gas, appears to be still obscure. One thing is certain, that the oxygen may be readily removed from the iron by the action of manganese."—[Roberts-Austin.]

What are known as "blowholes" and other unsound spots in cast-iron and steel are caused by occluded gases.

" Be it by increasing the solubility of gases, or by preventing the oxidation of carbon and the formation of carbonic oxide, manganese hinders the formation of 'blowholes.' "—[Howe.]

**Effects of Different Percentages of Manganese.** Manganese, in its action in alloys of iron, is probably the most remarkable of the elements usually found in pig and cast-iron and steel.

(a.) Mr. A. E. Outerbridge, in a lecture, delivered before the Franklin Institute in 1888, said: "A remarkable effect is produced upon the character of *hard iron* by adding to the molten metal,

a moment before pouring it into a mould, a very small quantity of powdered ferro-manganese, say 1 pound of ferro-manganese in 600 pounds of iron, and thoroughly diffusing it through the molten mass by stirring with an iron rod. The result of several hundred carefully conducted experiments which I have made enables me to say that the transverse strength of the metal is increased 30 to 40%, the shrinkage is decreased 20 to 30% and the depth of chill is decreased about 25%, while nearly one-half of the combined carbon is changed into free carbon; the percentage of manganese in the iron is not sensibly increased by this dose, the small proportion of manganese which was added being found in the form of oxide in the scoria." The points in this statement to be particularly noted are, 1st, that Mr. Outerbridge was experimenting with *hard or chilling* irons, which probably contained less than 2% silicon and in which the carbon was doubtless largely in the combined form; and, 2nd, the very small quantity of manganese added to the iron to cause such striking effects. The quantity of ferro-manganese was but 0.166% of the weight of iron; and, as it was doubtless 80% ferro-manganese, the actual addition of metallic manganese was but 0.133%.

Mr. Outerbridge does not speak of any examination, in these experiments, in regard to sulphur. But as the desulphurizing power of manganese is now well established, there can be little doubt that the remarkable effects he obtained were in some degree due to the desulphurizing action of the manganese and not wholly to its effect of forcing combined carbon over to the graphitic state.

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(b.) While we have no recorded tests of cast-iron containing 3, 4 or 5% or more manganese, by analogy any experiments along that line should show castings of a hard and brittle character. Spiegeleisen is pig-iron (cast-iron) containing 5% to 20% manganese, and is hard, brittle and crystalline. Steel containing 4% to 5% manganese is hard, brittle and of little strength. Hadfield mentions cast bars of steel 2½ inches square, 30 inches long, containing about 0.48% carbon and 4.9% manganese, which were so fragile that when dropped on a paved floor from a height of three or four feet, broke into several pieces. In tests for transverse strength such bars broke under a load of 3¾ tons, while similar bars of ordinary cast-iron stood a breaking load of 12 tons. Of such steel containing 4% to 5% manganese, he says: "No cohesion seemed to exist between the particles."

(c.) Passing to alloys of iron with higher percentages of manganese, we are brought to consider one of the most remarkable discoveries of recent years in metallurgy, namely, Hadfield's manganese steel. Hadfield found that when to decarburized iron was added 7% to 20% manganese the result was a new and, in many respects, a wonderful metal, combining great strength, toughness and hardness. A bar of this metal similar to those described (2½ inches square, by 30 inches long) stood breaking loads high as 38 tons, while tensile tests of 140,000 lbs. per square inch have been obtained. Unlike carbon steels, which are hardened (tempered) by heating and plunging into water, this metal, paradoxically, is somewhat softened and decidedly toughened by

heating and then rapidly cooling in water. Another peculiarity of this metal is that it is almost completely non-magnetic. A study of this remarkable metal is interesting, and for a full description of it reference is made to the proceedings of the Inst. of Civil Engineers, 1888. The most striking and useful results were obtained with the metal containing about 14% or 15% manganese.

This effect of manganese in percentages from 7% to 30%, as shown in Hadfield's steel, does not extend to cast-iron, for with these percentages of manganese in cast-iron we have spiegeleisen as the result.

What has been said under the heads (a,) (b,) and (c) is sufficient to illustrate the very different effects of various percentages of manganese in iron. The alloys of manganese with copper are interesting as well as very valuable in modern industry. Works on metallurgy describe these useful alloys, and there is also an interesting paper in Engineering, May 27, 1881, by Deshayes on these manganese bronzes.

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# PART II.

## Manganese in Foundry Practice.

"We still wonder at the minuteness of the quantity of certain elements which can profoundly affect the properties of metals."—[Roberts-Austin.]

Again the same celebrated metallurgist says, "It is difficult to describe briefly the effect of small quantities of manganese on the mechanical properties of carburized iron."

Manganese as used in steel and iron processes is generally in the form of spiegeleisen (20% metallic mang.) or ferro-manganese (80% metallic mang.) and in foundry practice the latter is generally used.

In considering the uses of manganese in iron foundries the subject may be divided under two heads, according to the purpose for which it is used,—first, softening hard irons, and, second, strengthening soft irons.

1st. The use of very small quantities of ferro-manganese for the softening, strengthening and purifying effects on hard or chilling irons. What has already been said of Outerbridge's experiments (page 10) is applicable here. Referring to these experiments, Turner says: (Metal. of Iron and Steel, 1895, p. 205.) "These observations accord with those made at Smethwick by the author, though in all probability their success depends on the peculiar composition of the cast-iron used." Again, the same authority observes: "From the examination of the tests conducted at Woolwich

in 1858, and numerous analyses of selected samples of cast-iron of *special strength*, the author concluded that the presence of some manganese was rather beneficial than otherwise in foundry practice, though probably any benefit ceases when the proportion of manganese is much greater than 1%. * * * Cases have come under the author's notice in which in actual practice ferro-manganese has been added in small quantity to molten metal in a foundry ladle, with the result that the iron has been very much softened and improved. The reason for this doubtless lies in the fact that manganese counteracts the effect of sulphur and silicon, tending to eliminate the former and neutralize the latter, and so, where common iron is employed, it sometimes happens that ferro-manganese may be used as a softener."

However, since Outerbridge made known the results of his experiments, and since Turner made the observations he mentions, the car wheel foundries during the last ten years have generally adopted the use of ferro-manganese and established the fact of beneficial results from its use in the class of work they make. The powerful action of a small quantity of finely ground or powdered ferro-manganese added in the ladle to chilling irons has gradually become known to them during the last ten years, and one after another they have adopted its use, and the fact that, when once adopted, they never change to their old practice, is good evidence that it yields results that are satisfactory. It enables the remelting of a very large proportion of old car wheels and similar scrap, and the use of grades of pig iron which formerly were not considered suitable for this class of castings. That there has been no deterioration,

but, instead, a great improvement in the quality of car wheels made by the method now used is shown by the fact that the severity of tests prescribed by railroads, and the guaranteed life or mileage of wheels have been raised repeatedly during the last ten years; and yet the car wheel makers have kept pace with these severer requirements, and have no trouble in making wheels by this modern method that easily meet these higher tests and guarantees.

The method followed by car wheel foundries is practically that described by Mr. Outerbridge,—the placing of a very small quantity of ground ferro-manganese in the ladle just before pouring, except that it is now customary to throw the ferro-manganese in the bottom of the ladle just as the iron is about to run into it. By this means the diffusion is immediate and complete, and there is no necessity to stir the metal. The usual practice is to put 1½ to 2 lbs. of the ferro-manganese powder in a ladle holding enough iron to pour a 600 or 650 lbs. wheel, the quantity and methods varying slightly with different foundries, apparently depending somewhat on their individual ideas, and the kinds of iron used to make up the wheel mixture. It is probable that 2 lbs. of ground ferro-manganese is sufficient in any mixture, for the largest car wheels, and possible that even a smaller percentage would prove equally effective. The real point sought in this case is not an increase in the manganese content of the casting, but it is the softening (chill-reducing), strengthening, sulphur-cleansing and reheating *effects* of the small dose of ferro-manganese upon the molten iron. It will be observed the quantity

of ferro-manganese used in the Outerbridge experiments was 0.166% and even where 2 lbs. is used for a 600 lbs. wheel the percentage is but 0.33, and as the ferro-manganese is 80% metallic manganese the percentage of manganese really added in the ladle in these cases would be 0.133 and 0.267. How much of this manganese remains in the iron, and how much escapes in the scoria or dross as oxide or sulphide of manganese? As far as known no determinations along this line have been made, but from the known tendency of manganese to oxidize, to unite with sulphur, and possibly to volatilize, it is fairly inferable that a very considerable portion of the manganese placed in the ladle is utilized in this purifying process and passes away in the scoria or gases.

Another advantage of using manganese in this manner which is worth considering is that, for chilled castings, it puts the regulation of the depth of chill under control after the iron is melted and ready for pouring. Enough of the molten iron can be taken in a small ladle to pour one or more chill test blocks. These are quickly cooled and broken, and show if the chill has been sufficiently reduced, if not, the charge of ferro-manganese powder is to be very slightly increased; if, on the other hand, the chill does not show depth enough, the charge of manganese must be slightly reduced. These tests can be made so quickly that there is no interruption to the operation of pouring.

Some years ago Mr. Wm. Wilmington patented a process for softening the hubs and plates of car wheels without affecting the chilled tread, by sprinkling powdered ferro-manganese into the head box after the mould is partly filled. It has

been claimed that new wheels were made in this manner entirely out of old wheels, without the use of pig iron. The error in the theory of this method is that it supposes that if the very small quantity of manganese used entered the iron which forms the chilled tread of the wheel it would in some way have a deleterious effect on the quality of the chill or increase its depth. That such effects do not follow where the manganese is added in the ladle and consequently is diffused through the entire mass of iron which makes the wheel has been demonstrated by Mr. Outerbridge's experiments and by the fact that the latter method has been adopted by wheel makers almost universally. Mr. Wilmington's method misses two important points—first, that the very purpose of using manganese in a mixture that would otherwise give too great depth of chill is, in a degree, to soften, toughen, and purify it, and the chill or tread of the wheel needs these effects as much as, if not more, than the iron which goes to form the hub and plate ; and, second, that of the very small quantity of manganese used some escapes, and even if it all remained in the iron as manganese content it is not sufficient to affect the chill or tread in the way he evidently figured it would. Wilmington's method would be a good one to follow where the iron mixture is just right to give correct depth of chill and it is desired to soften and toughen the plate and hub of wheels.

It should be constantly borne in mind that the method described on pages 15 and 16 is to be applied to mixtures of iron which, chilled, will have a greater depth of chill than desired, unless treated with manganese ; in other words, it is ap-

plicable to irons so hard and chilling in character that they require some softening.

It may not be out of place here to speak briefly of the influence of varying quantities of metals on each other, to show the decided effect of small quantities of one element on large masses of another element. Lord Kelvin has shown how very important the purity of copper is, and how remarkable is the action of the impurity. The presence of 0.1% of bismuth in the copper would, by reducing its conductivity, be fatal to the commercial success of the ocean cables. The addition to gold of 0.2% by weight of bismuth would, for coinage, convert the gold into a useless material, which would crumble under the pressure exerted through the die. Sir Hussey Vivian says that $\frac{1}{1000}$ part of antimony will convert the best selected copper into the worst conceivable. Instances of similar nature might be multiplied indefinitely, and nowhere are they more striking than in the effects of exceedingly small percentages of some elements upon iron.

2d. The usefulness of manganese in foundries making grey iron castings, where the mixture of irons used is generally soft enough, is probably not as yet so clearly established. There is a lack of recorded tests along this line. The mixtures of iron used in such foundries, whether the output is heavy or light machinery, stove plate, or some other class of grey castings, usually contains 2. to 3.% silicon, 3. to 3.5% carbon (of which the larger part is graphitic,) and more or less phosphorus, manganese and sulphur. The opportunity manganese has in such mixtures to show beneficial results is to increase the tensile and transverse

strengths, to partially eliminate sulphur and render the castings less liable to blowholes, by aiding the escape of gases. If there is already present in the mixture 1% of manganese any small addition which could be made without risking a hardening effect would be of doubtful value.

In a series of tests by Mr. W. J. Keep ("The Foundry," Jan., 1898,) for the effects of aluminum and manganese, used separately and together, he used mixtures of irons which, from the analysis of the test bars, ran about as follows :

| | | |
|---|---|---|
| Silicon | 1.60 to 2.25% | (Est. loss in melting.) |
| Manganese | 0.50 to 0.75% | " " " " |
| Phosphorus | 0.65 to 1.21% | |
| Graph. Carb. about | 3.00% | |
| Comb. " " | 0.35% | |
| Sulphur | 0 01 to 0.023 | (except one series, 0.05%) |

No statement is made as to the general character of the castings these mixtures made when untreated by manganese—as to whether they were of average strength, softness, etc. It may be judged, however, from the fair amount of silicon contained, the phosphorus, manganese and free carbon being fully up to the average, if not above it, and the unusually low sulphur, that the experimenter was working with good material, which should have made what are generally regarded as good strong, soft castings. As the irons used were unusually low in sulphur there was little room for the added manganese to show one of its best effects—desulphurization. It should be noted also that the irons were already above the average of foundry irons in manganese contents; and considering the silicon, phosphorus and free carbon present it would seem that, on the score of softness and fluidity, the irons needed no treatment. The net result of this series of tests, so far as the influence of the

additions of manganese is concerned, was an increase of tensile strength of about 9%, and of transverse strength of about 11½%. Mr. Keep does not mention any bad effects from thus increasing the manganese. The analyses of the several tests show increases of manganese contents varying from 0.310 to 1.111%, indicating additions of ferro-manganese in the ladle, we should judge, ranging from 0.50 to 1.50%. He remarks, "In the metal to which the ferro-manganese was added no blowholes were seen, nor any sign of excessive chill, although the shrinkage was slightly augmented." And again, "In every case but one (Series II) the addition of ferro-manganese increased the transverse strength without decreasing the deflection." In the last test (Series V) the untreated bars analyzed 0.55% manganese, and the treated bars (ferro-mang. added) analyzed 1.661%. This is an increase of 1.111% in manganese content, to obtain which it was probably necessary to add about 1.50% ferro-mang. in the ladle—possibly more. The bars from the regular mixture gave average tensile strength of 20,500 lbs. and transverse breaking strength of 1,965 lbs. The manganesed bars gave average 24,750 lbs. tensile, and 2,462 lbs. transverse strength. Here is an increase of 19% in the tensile, and 25% in the transverse strength. It should be further noted, that, while all these bars were cast to be 1 inch square, in the above test the exact measurements showed the manganesed bars to be smaller than the untreated bars,—which difference in size leaves something further in comparative strength to be credited to the manganesed bars.

As showing that the addition of manganese to

ordinary foundry mixtures will increase strength the following is quoted from an article by Mr. S. S. Knight in "The Foundry," Nov., 1897. "While using high manganese irons we found that our test bars made from these mixtures invariably broke higher than a corresponding mixture of low manganese metal. Scores of analyses were made to prove the cause of this phenomenon, and in every case high manganese was shown with no other phenomenal feature. Low manganese irons were tried having enough ferro-manganese added in the ladle to place the contents of this element over 1%. The results were the same as if originally high manganese iron had been used. The two test bars given below will show for themselves the advantage of gain in ultimate strength to be made in this manner. Both bars were cast on end and broken 36 inches between supports on a Riehle machine. having the load applied at the center with a uniform acceleration.

| | 1st Bar. | 2nd Bar. |
|---|---|---|
| Breaking strain | 928 lbs. | 736 lbs. |
| Deflection | 0.88 inch. | 0.97 inch. |
| Shrinkage, in one foot | 0.13 inch. | 0.12 inch. |
| Size of bar | .971″ x .950″ | .988″ x .990″. |

The first bar had a small amount of ferro-manganese added in the ladle, the iron being held until it flashed strongly before pouring. The analysis of the first bar was:

| | |
|---|---|
| Silicon | 1.980%. |
| Phosphorus | .558%. |
| Sulphur | .050%. |
| Manganese | 1.002%. |

The analysis of the second bar was practically the same as the first bar, except in manganese, which was .712%." It will be noted that the second bar was larger than the first, although both were evidently cast to be one inch square. The

increase of transverse strength shown in this case by the addition of a small quantity of ferro-manganese is 26%.

Some further examples along this line could be adduced to show that if, to an ordinary grey iron foundry mixture is added enough ferro-manganese to raise the manganese content to 1.% there is a decided gain in transverse and tensile strengths, and that up to this point the manganese manifests no undesirable effects. If the manganese is raised beyond 1.5% a distinct hardening effect will set in.

**The quantity of Ferro-Manganese to use, and method of using.** The most effective and economical way of adding manganese to cast-iron is to place powdered ferro-manganese on the bottom of the ladle and run the iron on it. The addition of lump ferro-manganese in the cupola has been found to be less effective, and not economical in ultimate results. When melted in the cupola the manganese is subjected to greater opportunities for loss and waste, through oxidation and volatility. The oxidation, to a certain extent, is desired and beneficial, but beyond that is wasteful. To the extent that it is beneficial it is obtained by adding in the ladle. Howe states that oxide of manganese gives slags so strongly corrosive that their effect on the linings of open-hearth, cupola and other melting furnaces must be guarded against.

*In hard or chilling irons*, to soften, to regulate, or reduce chill, or prevent increase of chill on remelt, —several expressions of the same influence—the practice already described as Outerbridge's or the car wheel foundry method has proven to be the

best. Probably the best starting point is 1 lb. of ground ferro-manganese to about 300 lbs. of iron. If this does not produce the exact effect wished, the dose may be very slightly increased or decreased, according as it is desired to increase or lessen the softening effect. It may prove that a proportion of 1 lb. of ferro-manganese to 400 lbs. iron will yield the best result, considering the character of the work in hand and the irons forming the mixture, or again 1 lb. to 250 lbs. may give better results. Where the mixture is of chilling irons, either pig, old car wheels or other scrap of that character, the manganese is used to modify the chilling tendency of snch irons, and at the same time to otherwise improve the iron. It is best to use the ferro-manganese in the shape of a uniform powder, of about the grain of sand. If it is finer the heated air rising from the ladle carries some of it away in dust; if it is too coarse there is not the requisite instantaneous diffusion and reduction by the molten metal. The nearer instantaneous is the diffusion and reaction in the ladle the more effective it is—and, to a certain extent, the less the quantity required to produce a given effect.

*In grey iron foundry mixtures*, where manganese is added primarily to stengthen and incidentally to prevent blowholes and otherwise improve the iron, about 1 lb. of the ground ferro-manganese to 200 lbs. of iron will usually be approximately the proper proportion. Something depends upon the manganese contents of the mixture before treatment. If the manganese content of the iron to be treated is known add enough ferro-manganese in the ladle to raise the percent-

age of that element in the casting to 1.%. If the castings are of a class that some degree of softness can be spared to secure greater strength the percentage of manganese may be raised to 1.25% In calculating the weight of the dose of ferromanganese to be added bear in mind it is 80% or four-fifths metallic manganese. It must also be figured that there is some loss of the manganese as part of the beneficial action which takes place in the ladle, by oxidation and escaping gas. What the extent of this disappearance of the manganese will be in any case would be difficult to state. It may safely be figured at one-fourth or more of the quantity charged.

In other words, where the object is *to strengthen* soft grey iron, manganese may be added to the extent of about 1%, or 1 lb. manganese to 100 lbs. iron.

If, however, the object is *to soften* grey iron which would otherwise produce hard castings, and, incidentally, to somewhat strengthen and generally improve the castings, the dose of manganese must be kept small—say 1 lb. manganese to 300 lbs. of iron.

The results of this inquiry into the character, influences and value of manganese in iron castings may be briefly summed up as follows:

1. Used in very small proportion it acts to soften chilling irons or hard iron.

2. Used in somewhat larger proportion, say 1%, it acts to strengthen soft irons.

3. It aids the escape of gases, thus reducing the chance of blowholes or unsound castings.

4. It acts strongly to eliminate sulphur.

5. In the case of chilled castings, car wheels, etc., it puts the regulation of depth of chill under control, after the iron is melted and ready to pour.

6. Whether it is hard iron or soft iron that is treated with an addition of manganese there is a general improvement of the iron, in solidity, toughness, etc.

There will doubtless be some first failures to secure desired results, but experience will show that manganese is a valuable adjunct in foundry practice for nearly all classes of castings.

PUBLISHED BY KENDALL & FLICK, WASHINGTON, D. C.

Published by

KENDALL & FLICK
MANGANESE
WASHINGTON, D.C.